INTERHARMONICS AND LED FLICKER: AN ASSESSMENT BY CFD

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ABSTRACT

Light emitting diodes (LED) as light source are becoming the standard, as the mature technology is economical interesting and environment-friendly. The change from classic lighting to solid state lighting (i.e. LED) gives in practice several problems. The influence of harmonics and interharmonics on LED is researched. The specific flicker problem mentioned in several papers and the relation to harmonics is assessed by using the Compact Flicker Degree (CFD) method. The assessment is done for both dimmable and non-dimmable LED.

INTRODUCTION

Switching to LED lighting is a sustainable and economically interesting choice for both new construction projects and renovation. The use of LED as light source has become mainstream, due the undeniable benefits, both economical and environmental. It is known that switching from classic lighting to LED lighting is not always without problems. But where do these problems originate from? In order to gain a deeper insight into the problems research was done to further analyse various problems. In this paper, the flicker problem is discussed.

Flicker is defined as '*the impression of unsteadiness of visual sensation induced by a light stimulus whose luminance or spectral distribution fluctuates with time*' [1]. It is a variation of light intensity over time, typically caused by voltage fluctuations at the LED's terminal voltage. These voltage fluctuations are caused by other loads imposing voltage fluctuations on the grid. The voltage fluctuations generated by loads are assessed according to IEC61000-3-3 [1], which defines the measurement setup and limits. The measured values are processed (weighted) with a flickermeter described in IEC61000-4-15 [2], which convert the fluctuations into flicker severity factors.

Flicker can be visible, but also invisible and is undesirable from a certain degree. Visible flicker is typically low-frequency and is perceived as annoying. For example, it is known that an 8 Hz variation is experienced as the most disturbing flicker frequency for people. Invisible flicker does not disturb directly on humans, but because the eye continuously adjusts to the light intensity, long-term exposure results into fatigue, headaches and reduced concentration. In Lemcko a measurement setup was provided to measure the light intensity.

The here presented research focuses on flicker induced by harmonics and interharmonics. For evaluating the optical flicker, the Compact Flicker Degree method (CFD) is used [3]. CFD has been used to evaluate flicker of different light sources, including LED, but not in combination with voltage distortion.
The paper is further elaborated as follows. The first section describes the measurement and evaluation method. The second section describes the results when LED lights are evaluated under distorted conditions. The last section describes the results when LED with dimmers are evaluated under the same conditions.

MEASUREMENT AND EVALUATION METHOD

Measurement method

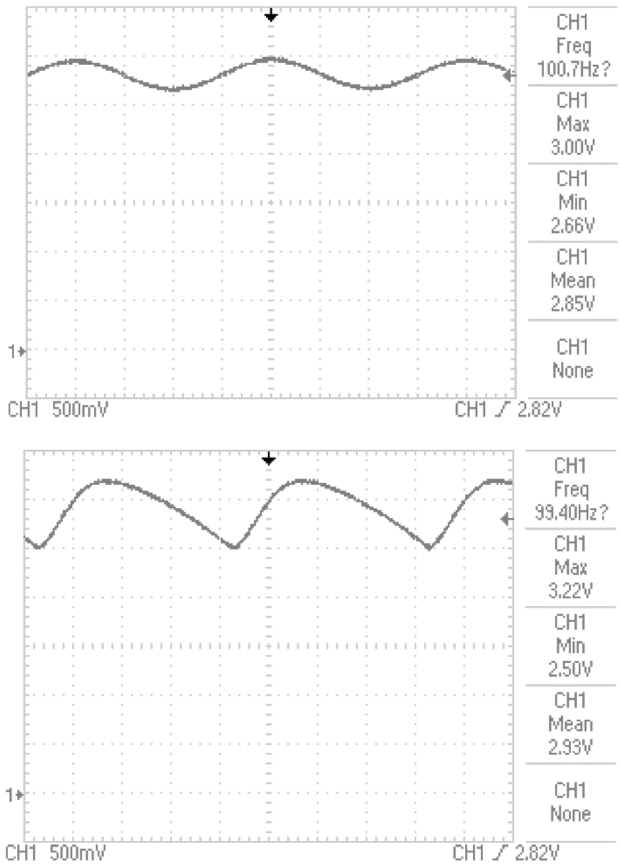

Figure 1. Light intensity incandescent lamp (top) and CFL (bottom)

The measurement of the optical flicker is performed with a light sensor based on the TSL257 light to voltage converter. The bandwidth of the system is 2,2 kHz [4] which is sufficient for the assessment. Fig. 1 shows the variation in light intensity of an incandescent and a compact fluorescent lamp (CFL). Both technologies clearly show the double mains frequency (100 Hz). Fig. 2 shows the same for LED lighting. Here a clear difference can be noticed. With one LED there is a 100 Hz variation, with the other LED the intensity is constant.

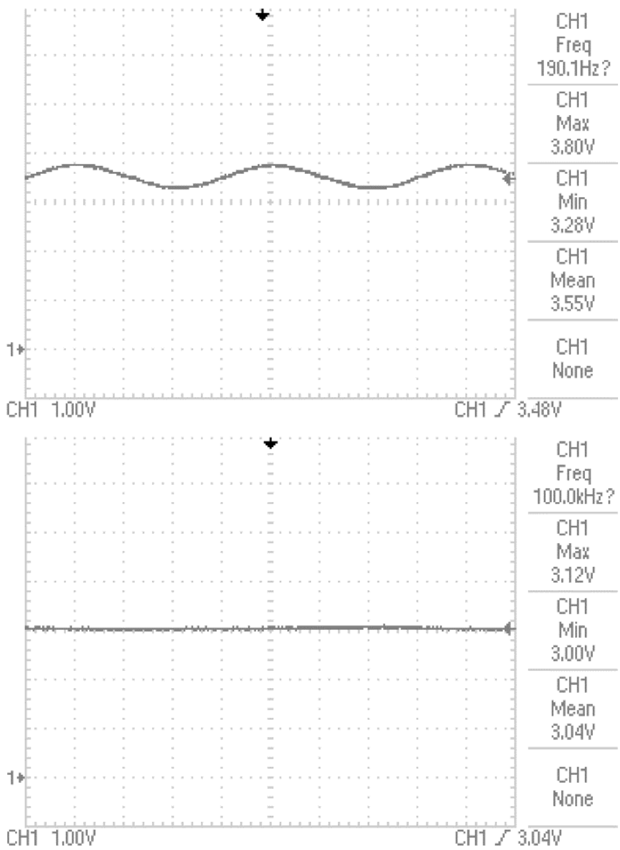

Figure 2. Light intensity different LED

The difference is due to the internal power source of the LED. With one LED the light intensity is proportional to the current, not to the voltage. A constant luminous flux therefore requires a current control, which is the case for the LED in the bottom measurement of fig. 2.

The measured variations of 100 Hz, present in the different lighting technologies, are not a problem. The reason for this is that 100 Hz is too fast to be problematic for the eye. Flicker can be seen up to 70 Hz. Given the double frequency in the light intensity, this means that at normal mains voltage there is no problem with flicker. How problematic flicker is depends on both the size of the variation and the frequency of the variation.

Compact flicker degree (CFD)

In literature different evaluation methods are present. An example is IEEE 1789 [5], based on maximum and minimum light output values. This method shows several deficiencies as described in [3].

To cope with this problem, the Compact Flicker Degree (CFD) method was developed. The objective assessment of visible flicker was done in this study using CFD. In this method, the light waveform is taken into account. The light intensity is converted into an electrical voltage (Figs. 1 and 2). The spectrum of this waveform is determined. Depending on the frequency, a different weight is assigned (Fig. 3) to take into account the eye sensitivity and the specific response of humans to certain frequencies.

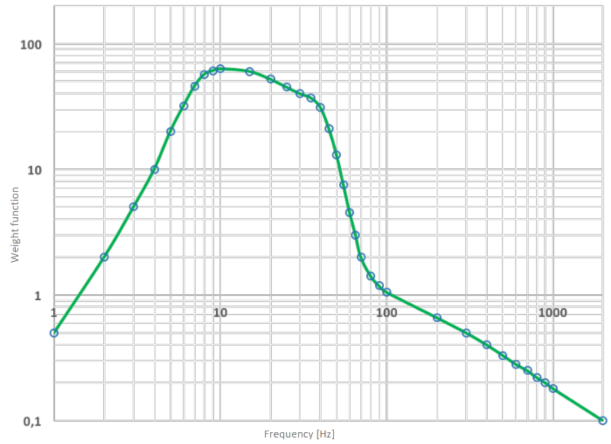

Figure 3. Weight function CFD

The interpretation of the CFD is divided into several categories. Each category is assigned a colour.

Table 1. CFD categories of severity

CFD	Color	Observation/consequences
1% to 12%	Green	Not noticeable
12% to 25%	Yellow-green	Acceptable
25% to 50%	Yellow	Low influence – less suitable for working environments
50% to 75%	Orange	High influence – physical complaints after long-term exposure
> 75%	Red	Extreme influence

INFLUENCE OF HARMONICS AND INTERHARMONICS ON LED

Different LED were measured (fig. 4). The solid state lights were powered by a programmable source. Each voltage contained a specific harmonic or interharmonic. The low order harmonics (3rd to 11th) were measured with different phase shifts compared to the 50 Hz fundamental. As interharmonics, the possible RC-signals (ripple control) were considered. The grid operator uses the RC-signal to send messages over the grid. These messages are used for various purposes, such as switching street lighting or switching between day and night electricity tariffing. The RC-signals are superimposed on the 50 Hz voltage. The frequency range is defined in the standard EN 50160 [6] between 110 Hz and 3000 Hz, as well as the maximum amplitude. Typical frequencies used in Belgium are 180 Hz, 185 Hz and 283 Hz. The harmonic 1350 Hz is also used. For these frequencies it is useless to use a phase shift, as they do not run synchronously with the fundamental.

The result can be seen on fig. 4. Only LED B is dimmable. There are clearly large differences between the different LED. It is striking that lamps D and E have a lower quality in terms of light output, even at a pure sinusoidal voltage. These lights are preferably not used as workplace lighting. For all LED, the harmonics and reduction of voltage by 6% (noted as damping) have a limited influence on the CFD. The CFD changes little compared to the ones measured at a pure sinusoidal voltage and remains for these situations always within the same severity category.

The most important conclusion that can be taken is that interharmonics for a large part of the lamps cause an increased CFD. For six lamps this is to such an extent that the result lies in the red zone. This is largely in line with the visual observations, as only visible flicker was observed during measurements with interharmonics.

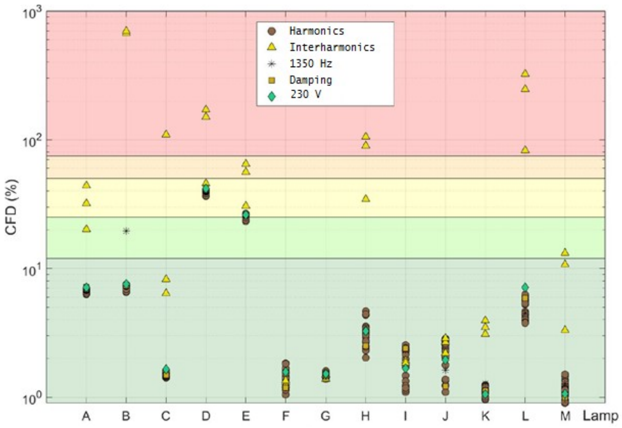

Figure 4. Influence of (inter)harmonics on the flicker behavior of different LED

INFLUENCE OF HARMONICS AND INTERHARMONICS ON LED WITH DIMMER

In the next step a suitable dimmer is used for the LED. Fig. 5 shows that again the interharmonics cause problems. Fig. 6 further shows that even with limited amplitude of the interharmonic the flicker is already problematic. The reason for this large influence can be found in the operation of the dimmers. These are based on the zero crossing detection of the voltage to make the semiconductors switch. When imposing harmonics, the zero crossing can change, but this change is constant, so there is no detectable flicker. This can specific be noticed for the harmonic RC-signal of 1350 Hz. With interharmonics, the zero crossing changes with each period, because the interharmonic and fundamental are not synchronized. The fact that interharmonics cause problems on CFL and LED was already discussed in [7]. This was based on visible flicker detection by objective measures. By using CFD, both visible and unvisible flicker are weighted.

Figure 5. CFD results for LED with dimmer subjected to voltages with harmonics or interharmonics

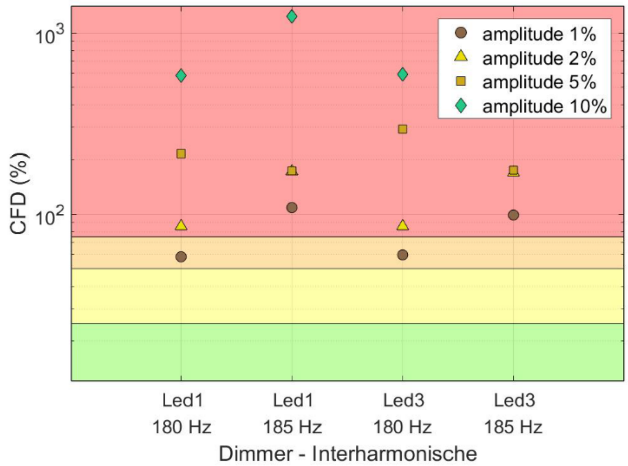

Figure 6. Influence of interharmonic frequencies and amplitude on LED with dimmer

SOLVING PROBLEMS

To solve the problem, LED designers should take care of this phenomenon in their design. After prototyping the system, flicker testing based on interharmonic distortion should be part of the testplan. Nowadays, technicians are limited to use LED from different manufacturers to see if the problem is solved. For persistent problems, RC-filters are recommended. Finally, not every flicker is due to interharmonics. In most cases the problem is the compatibility between the LED and the dimmer.

CONCLUSION AND FUTURE WORK

The research showed that especially interharmonics have a large influence on the optical flicker behaviour of the LED. Researched interharmonic frequencies are the used RC-signals. For the evaluation the CFD method proved to be a valuable method. Future work will focus on the influence of power line communication signals and emission in the range 2 – 150 kHz.

Acknowledgments

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